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ASSESSING THE SOLAR-GROUND STILL PERFORMANCE FOR DIFFERENT DEPTHS OF SALINE WATER: AN EXPERIMENTAL STUDY

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ABSTRACT

In this study, experiments are carried out on a single slope single basin passive solar-ground still, which exploits ground heat for the continuation of the fresh water production during late evening hours, for different depths of the saline water. An attempt has been made to utilize the maximum amount of solar energy and to alleviate the heat losses from the bottom and side surfaces of the still. The fabricated Solar-Ground still possesses no bottom insulation and its side surfaces are covered by sand. As the ground layer in contact with the still, functions both as sensible heat storage medium and insulation film, the excess heat energy is absorbed during noon hours is released back to the basin during late evening hours. This causes the temperature difference between the basin water and glass surfaces increases and thus boosts the evaporation rate. The daily productivity observed for the 20mm, 30mm, 40mm water depths is 2.01 kg/m^2, 2.45 kg/m^2 and 2.19 kg/m^2 respectively. To show the effectiveness of the modification, solar-ground still performance is compared with traditional still for 30 mm water depth, under the same climatic conditions and 17% increment in daily productivity is observed.

***KEYWORDS:** Solar-Ground Still, Water Depth, Saline Water Temperature, Daily Productivity & Ground Heat*

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Original Article

INTRODUCTION

Safe drinking water is one the most basic needs for human beings. Water circulates continuously through the atmosphere, ground and inhibiting organisms. Its presence is masked in various forms and phases such as ground or surface water, as salty or sweet water, as icy glaciers, vapors…etc. Reportedly, a whopping ninety-seven percent of the earth water is contained in oceans. About two thirds of the remaining 3% is available in the glaciers of Antarctic and Arctic regions with just 0.5 % of brackish water, which is not fit for human consumption and leaving only 0.5% as fresh water. In order to be at par with the quality standards of the safe drinking water, a household is recommended to use an improved type of water source which meets following three criteria. First, the facility should be accessible on the premises. Second, water should be available when needed. Third, water should be free from any contamination. Solar still is a simple, cost-friendly desalination unit which satisfies these criteria and is the best-suited water desalinating unit for those living in arid, semi-arid, remote regions lacking electricity supply. Amid the expensive desalination technologies, utilizing the solar it is a freely and abundantly available

renewable energy source.

M Sakthivel & S Shanmugasundaram [1] experimentally proved that without any extra cost solar still performance can be improved by about 20% when the energy storing materials (black granite gravel) are employed. Also found that maximum e□ciency of the solar still with black gravel is 8% higher than the traditional still. M Sakthivel et al.[2]tested the performance of a regenerative solar still experimentally by placing the jute cloth in the vertical position at the middle of the basin water and by attaching to the backside wall of the still. Showed that the cumulative distillate output and efficiency of the modified still are increased by 20% and 8% respectively. Many heat absorbing materials viz. copper, paraffin wax, cotton cloth, sponge, aluminum.. etc. enhances the still productivity but using sand is more economic since it is abundantly available and also an effective sensible energy storing medium under Indian climatic conditions [3]. D Tiwari and Ajeet Kumar Rai,[4] experimentally investigated the performance of a solar still using Al turning in the basin as the sensible energy storing material and observed the output distillate increased in both diurnal and nocturnal hours. Found that still's daily productivity is enhanced by 35% and also observed that by increasing the amount of Al turning from 3kg to 5kg led to an increment by 10%. K Udayabharathi et al.[5] studied the performance of the wick type solar stills integrated with fins and observed 53% improved daily productivity. Distilled water output was increased by about 14% - 34% by using different orientation angles and reflectors. W Parekh et al. [6]performed an experimental analysis on basin solar still for varying water depths ranging from 1 cm to 6 cm and concluded that at an optimized water depth of 30 mm, still produced maximum daily productivity of 2.6 liters/day over the rest.

Miguel Diaget al.'s [7] experimental results on the sand showed that that natural desert sand could be preferred as an excellent energy storing material for sensible heat thermal energy storage (TES) applications. A. E. Kabeel &Mohamed Abdelgaied[8] experimentally found that improvement of daily productivity of about 67%–68.8% was observed due to the impact of PCM in solar stills. T Sathish Kumar & Raja Bharathi[9] experimentally assessed the effect of water depth on the performance of solar still and observed that the maximum productivity is obtained at 30 mm thickness of water mass and is 11 % higher over the traditional still. D. G. Harris Samuel et al.[10]experimentally and theoretically investigated the solar still performance using a sponge and salt spherical balls as energy storing mediums and observed 50% and 8.3% higher daily productivity output respectively.

In this work, experiments are conducted on the solar-ground still at different water depths to optimize the still performance and results showed that the solar-ground still produce maximum daily distillate output for 30 mm water depth and 17% higher daily productivity over the traditional still is observed.

EXPERIMENTATION AND METHODOLOGY

The sectional diagrams of the traditional still and the designed solar-ground still are shown in figure 1 and figure 2 respectively. Solar-Ground Still has a rectangular basin with 0.75m × 0.50m area and is fabricated by bending, assembling and soldering a 2 mm thin galvanized iron sheet. Inner surfaces of the basin are coated matte black to absorb maximum solar energy. Besides to being insulated by 35 mm thick rock wool and thereafter by 10 mm thick wooden plates, side surfaces are further covered by sand. Basin bottom is kept in direct contact with the ground without any insulation in between. A 4 mm thick glass cover is mounted at 23^0 inclinations over the top of the still. PVC channel is fixed to the glass cover lower end to collect the condensate. A graduated measuring jar is used to store the fresh water produced. Two holes, to feed in the saline water and to insert the thermocouples, are made on the side surfaces and a drain is provided at the

bottom for cleaning purposes. The whole system is made vapor tight by using an elastic sealant. The Solar-Ground still is placed such that glass cover faces the south. Calibrated K type thermocouples are connected to a digital temperature indicator and are fixed to the still components at different points to record the temperatures of the glass cover, saline water, basin, ground, and the ambient air. Solarimeter is placed near the glass cover to measure the hourly solar radiation intensity.

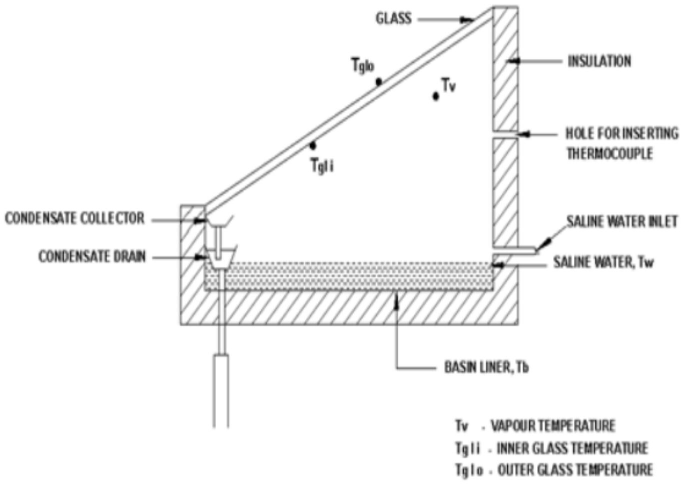

Figure 1: Sectional view of the Traditional Still

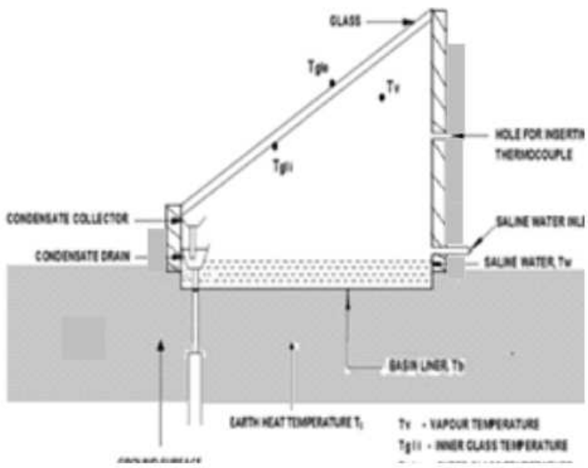

Figure 2: Sectional View of the Solar-Gr still

Observations viz. Solar radiation intensity, temperatures of the glass cover, saline water, basin, ground surface, and the ambient air are taken for each hour from morning 10am to evening 7pm during the experiments for 20mm, 30mm, 40mm depths of saline water. Photographic views of traditional still and solar-ground still are shown in figure 3 and figure 4 respectively

Firstly, experiments are conducted repeatedly in the solar-ground still for a definite level water depth under the same operating conditions for several days to get the close values of the observations. Then, experiments are conducted for different levels of water depths under the same meteorological conditions to compare the still daily productivity and to find the optimum water depth. As the maximum daily productivity has been recorded for the 30 mm water depth, again

experiments are conducted on a traditional still at the same optimum saline water depth and under the same climatic conditions, to find out the percentage of increment in the solar-ground still productivity over the traditional one.

Based on the observations recorded and the accuracy of each measuring device the experimental uncertainty is estimated at about 2.5 % by following the procedure explained by R Moffat. [11].

Figure 3: Photographic view of Solar-Ground Still

Figure 4: Photographic View of TRADITIONAL STILL

RESULTS AND DISCUSSIONS

In this study, effect of the modification on the saline water temperature, the effect of the water depth (water mass) on the daily productivity of the solar-ground still and the effect of the recouped ground heat from the ground to the basin (during the late evening hours) on the performance of the solar-ground still have been analyzed.

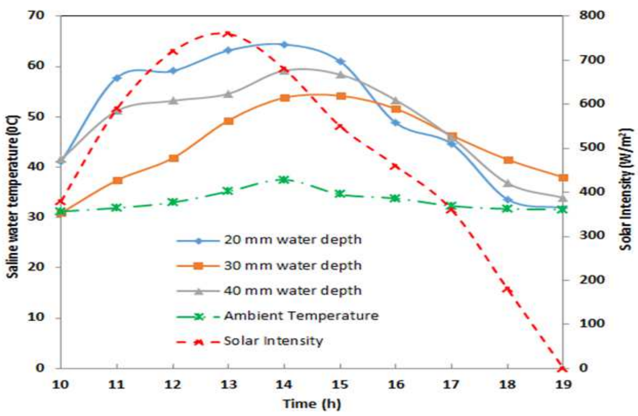

Figure 5: Variation of Saline Water Temperature

Figure 5 shows the variation of saline water temperature and variation of climatic parameters (Solar intensity and ambient temperature) with time. It can be understood from the graph that, for the 30 mm water depth case, during the late evening hours, the saline water attained higher temperatures and remained higher for a longer time, compared to 40mm and 30mm water depths. This effect heats the saline water in the solar-ground still basin and keeps it warmer so that aids the evaporation rate which results in higher daily productivity.

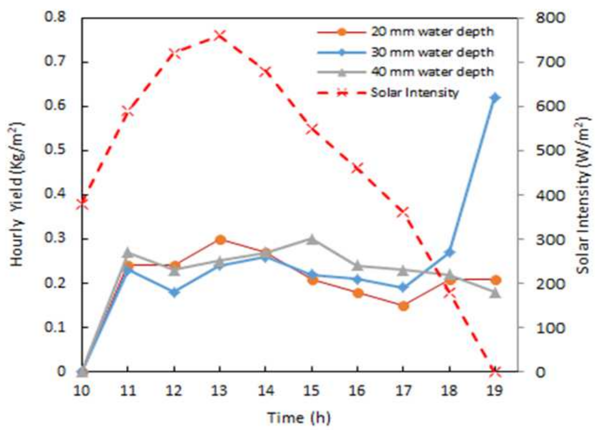

Figure 6: Variation of Hourly Productivity

In figure 6, the variation of the hourly productivity with time for 20mm, 30mmm, 40mm water depths is shown. It can be predicted that solar-ground still’s hourly productivity at 30mm water depth is maximum at 1pm and is around 0.25 kg/m2. It was about 0.2 kg/m2 during 11am to 12pm, reaches 0.68 kg/m2 during the 1pm to 4pm. For the rest of the water depth cases, the hourly productivities are comparatively lower. During the evening hours (after 5pm), a sharp and steep increase in the hourly productivity was observed up to 7pm.

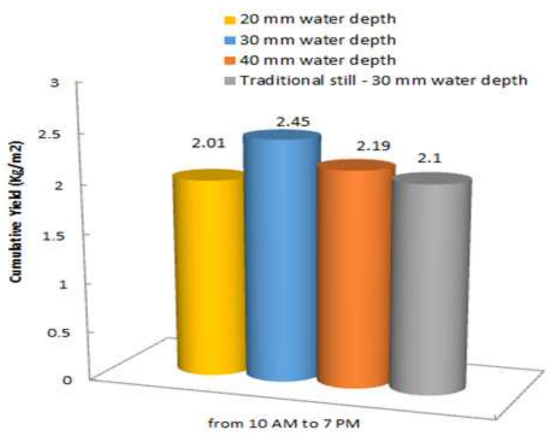

Figure 7: Variation of Daily Cumulative Productivity

Figure 7, presents the total daily productivity of the solar round still for the operating water depths conditions and the daily productivity obtained by the still for 30 mm water depth under the almost same climatic conditions. It shows that, in the case of solar-ground still, for a level of low water depth (20 mm), the productivity is also low (2.01 kg/m2) and rises with the water depth (30mm) to 2.45 kg/m2and again begins to decrease to 2.19 kg/m2beyond certain depth of water. Thus, 30mm of water depth can be assessed as the optimum level for the maximum daily productivity of the solar ground still. For traditional still, obtained distillate output for 30 mm water depth under the almost same climatic conditions is

2.1kg/m2. Hence, 17% increment in daily productivity is observed for the solar-ground still over the traditional one.

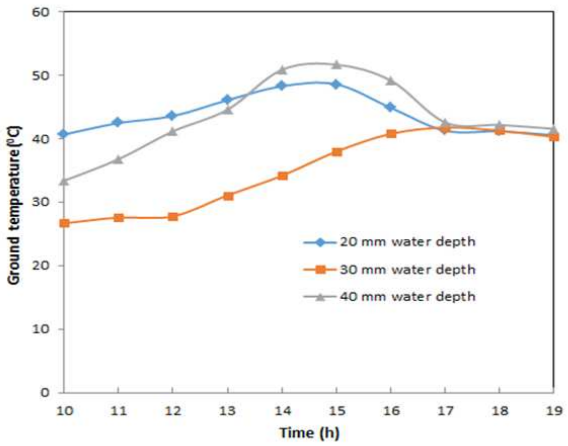

Figure 8: Variation of Ground Temperature

Figure 8, shows the ground surfaces temperature variation with time for different water mass (water depth). During the late evening hours from 5pm to 7pm, the difference in the ground temperatures is higher for 30mm water depth case (1.50C), when compared to 20mm, 40mm thicknesses of water mass (0.70C and 10C respectively). Meanwhile, for the 30mm thickness of saline water, from 5 pm to 7pm time period, higher temperatures are attained and lasted by the saline water in the solar-ground over the rest. This shows maximum ground heat is utilized to heat the saline water for optimum water depth (30mm) in the absence of the significant solar intensity.

CONCLUSIONS

In our research work, the effect of ground heat on the performance of the solar-ground still is studied experimentally for different saline water mass. From the analysis, we can conclude the following,

- This kind of desalination unit has an added advantage of utilizing the ground heat to augment the daily distillate output.
- Solar-Ground still's daily productivity for the water depths of 20mm, 30mm, 40mm is observed as 2.01 kg/m^2, 2.45 kg/m^2 and 2.19 kg/m^2 respectively
- 30mm saline water depth is found to be the optimized level for the maximum solar-ground still performance.
- 17% more daily output of fresh water, over the traditional still, is recorded.
- The modification applied to the still is proved effective and demands no extra costs.

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